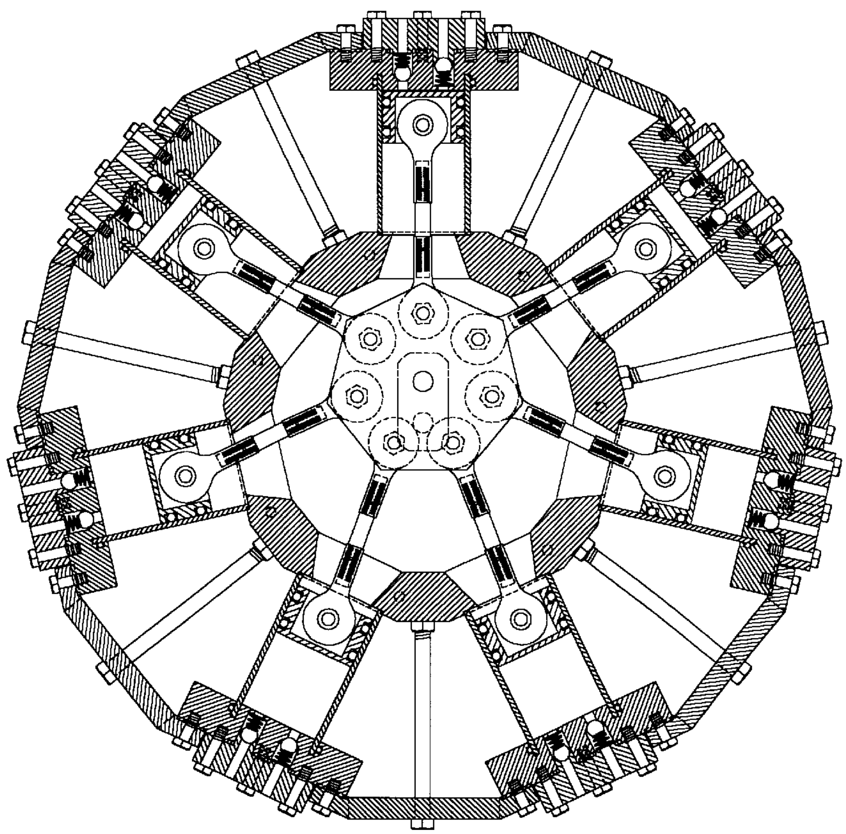
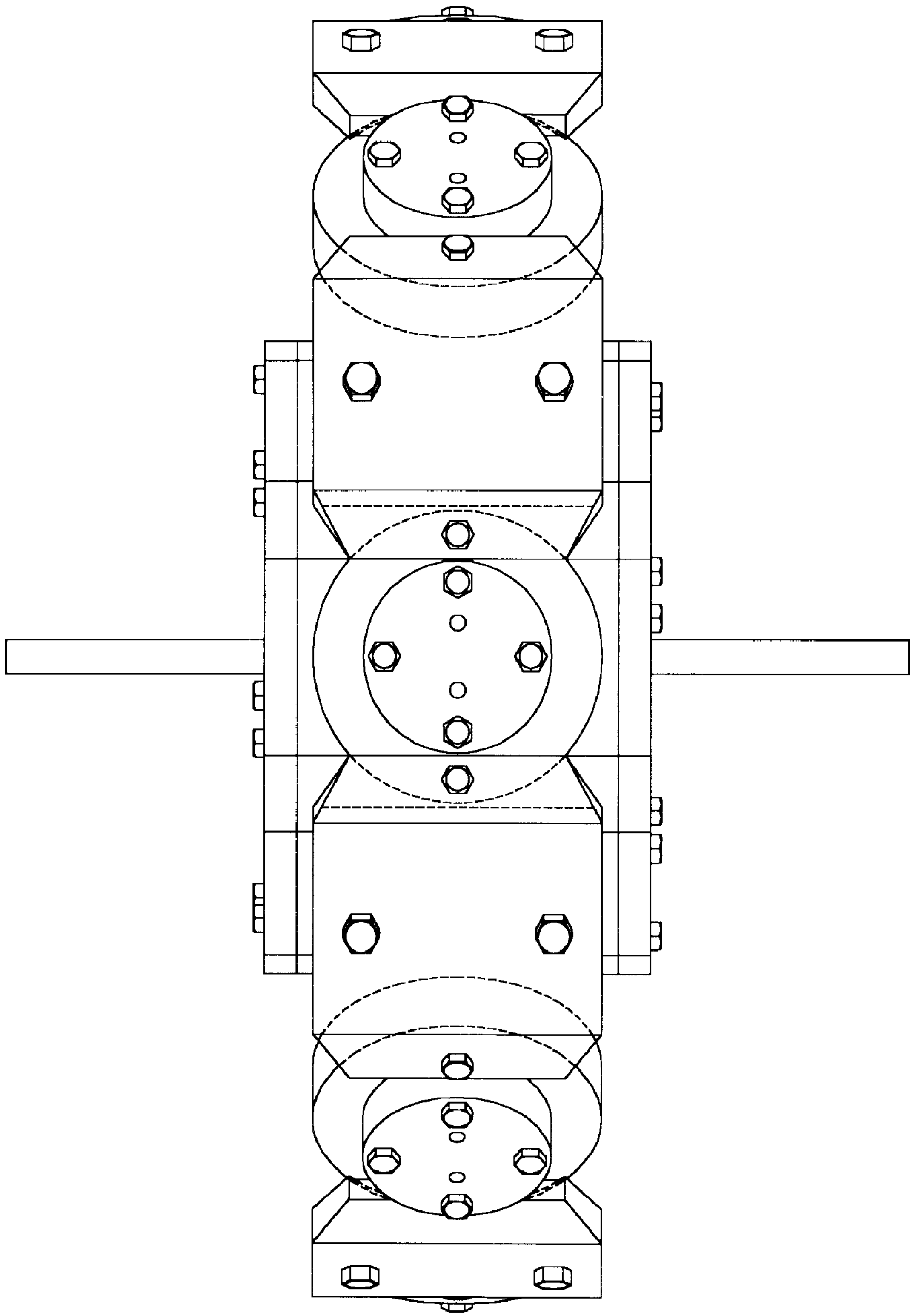
RADIAL PULSATION-GENERATING COMPRESSOR
(untested)

CONTENTS



FRONT VIEW



THE CONCEPT

This is an idea, not a blueprint or a set of plans. It has not been tested.

The idea was to provide a simpler version of Bob Neal's compressor as shown in his US Patent #2,030,759. Neal's compressor unit was a poured block designed to replace an auto engine. We have no important details of the engine that are not included in the patent and our interview with Bob Neal's son. Please reference our book The Magic Valve.

This radial compressor concept is a departure from the V- or flathead engine configuration that Bob Neal used. This idea uses Black Amalgon cylinder tubing, a filament-wound machinable tubing made of epoxy impregnated with Teflon. It does not require lubrication. However, no attempt was made to evaluate the thermal properties of the material for use as compressor cylinders. It is normally sold for use in actuator cylinders (air powered pistons for moving and positioning, providing a power push, etc.) Most compressor cylinders incorporate fins to radiate heat, which this material obviously does not. Fins could be added to the heads which are held onto the tops of the cylinders by tie-rod bolts.

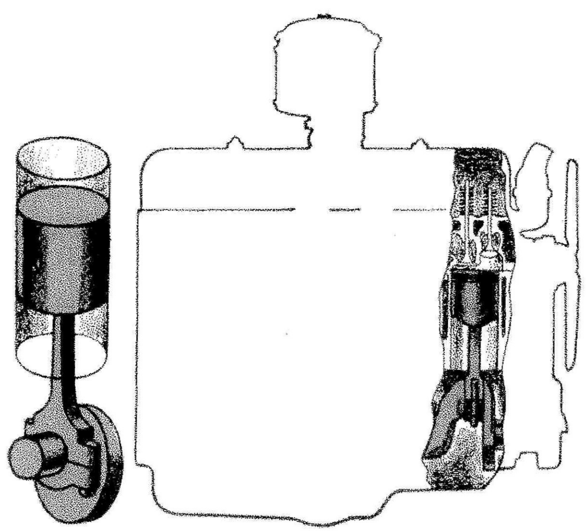
The idea was to design a bolt-together system using no castings and little or no welding. Simple o-ring seals are called for in all locations. Simple ball-and-spring check valves are called for. The parts would have to be made by a machine shop. The drawing is not dimensioned because it is not a complete design ready to build. No engineer has evaluated this design for needed strength or safety.

Obviously there is room for improvement in this design, but it is a place to start. It has been assumed that the Neal tank is replenished by providing a pulsating intake of ambient air compressed to a lower pressure than the tank it's going into. The pulsating air would build up pressure and rarefaction waves by means of reflection/compounding in a series of check valves tuned to a resonant frequency by proper spacing.

WE now have a complete engine. We have not attempted to discuss every part in detail, but we have put together an engine that will run and keep on running.

With proper provision for air, fuel, and ignition we have an engine that will run. We add cooling and lubrication to make sure that it keeps on running.

This is an automobile engine. It may be used for other purposes, but it is primarily to drive an automobile. But we have other types of engines which it is now time to look into. This will be easier than our consideration of the automobile engine, because we have already covered much of the ground. A large part of what we have explained applies equally well to aircraft and Diesel engines. The fundamentals are the same. The main job will be to point out the differences — what it is that makes one an aircraft engine and another an automobile engine. As before, it will be principally a matter of finding out how each type gets its AIR, FUEL, and IGNITION.



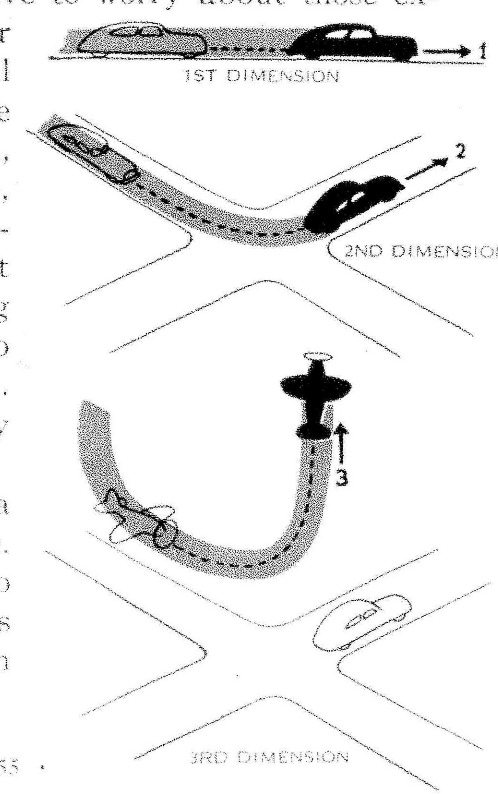
AIRCRAFT ENGINE

PRACTICALLY all the things which make an aircraft engine different from an automobile engine are the result of one fact — we have a *Third Dimension* to take into account.

As soon as we leave the ground we have a new set of conditions. And when we get 7 or 8 miles above the earth, where planes are flying today, those new conditions become extreme. The air becomes very thin, the temperature may be almost 200 degrees colder than when we took off. Those are things which must always be kept in mind in designing an airplane engine.

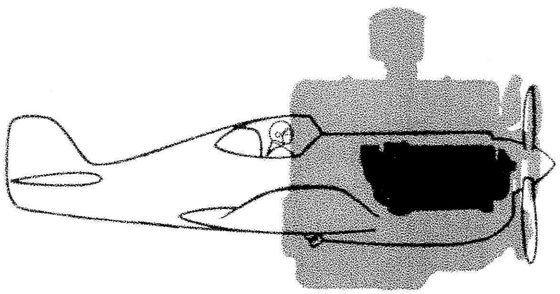
But long before we have to worry about those extremes, we run into another problem. In an automobile all the engine has to do is move the car along the ground, fast or slow. In an airplane, the engine has to move it forward fast enough to keep it up in the air, and in taking off from the ground it has to furnish the power to lift it up. The plane is fighting gravity all the time.

This makes weight a matter of great importance. Every extra pound built into the plane means a pound less gasoline or pay load which can be carried.

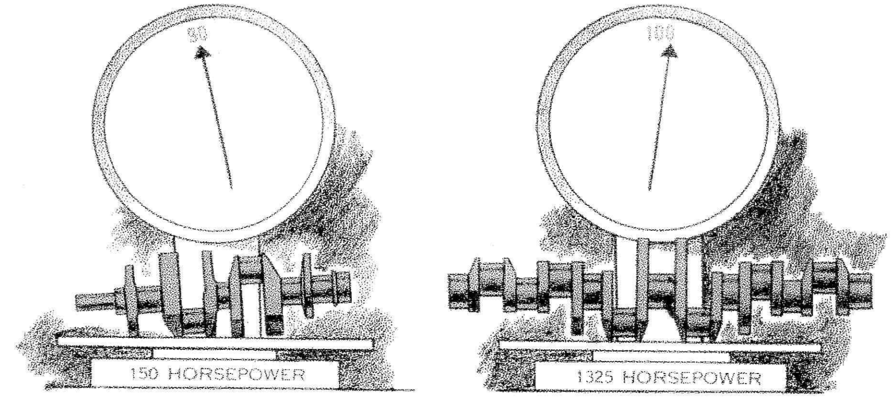


All parts of an airplane are engineered with the idea of making them as light as possible. And the engine is no exception. In some fighter planes the engine alone, not including most of its controls and the extras that must go along with it, accounts for more than a quarter of the entire weight of the plane. If we built this engine the way we do automobile engines, it would weigh considerably more than the present complete plane and engine. Thus we can see why the aircraft engine builder is constantly trying to produce engines with as much power and as little weight as possible. As the engineer would put it, we want a high power-weight ratio.

Some of the results of this striving for lightness can easily be seen in just looking at an aircraft engine. It shows up in two ways—*materials* and *workmanship*. The lighter metals, aluminum and magnesium, are used wherever possible, even though it makes the engine cost more. Every part is cut down to be as small and light as it can be made and still do its job efficiently and safely. An ounce of metal in an aircraft engine is doing a lot more work than an ounce of the same metal in an automobile engine. This means it is stressed more—there is more tendency for it to tear apart or break. Therefore the workmanship and finish must be as perfect as modern machines and skilled craftsmen can produce.



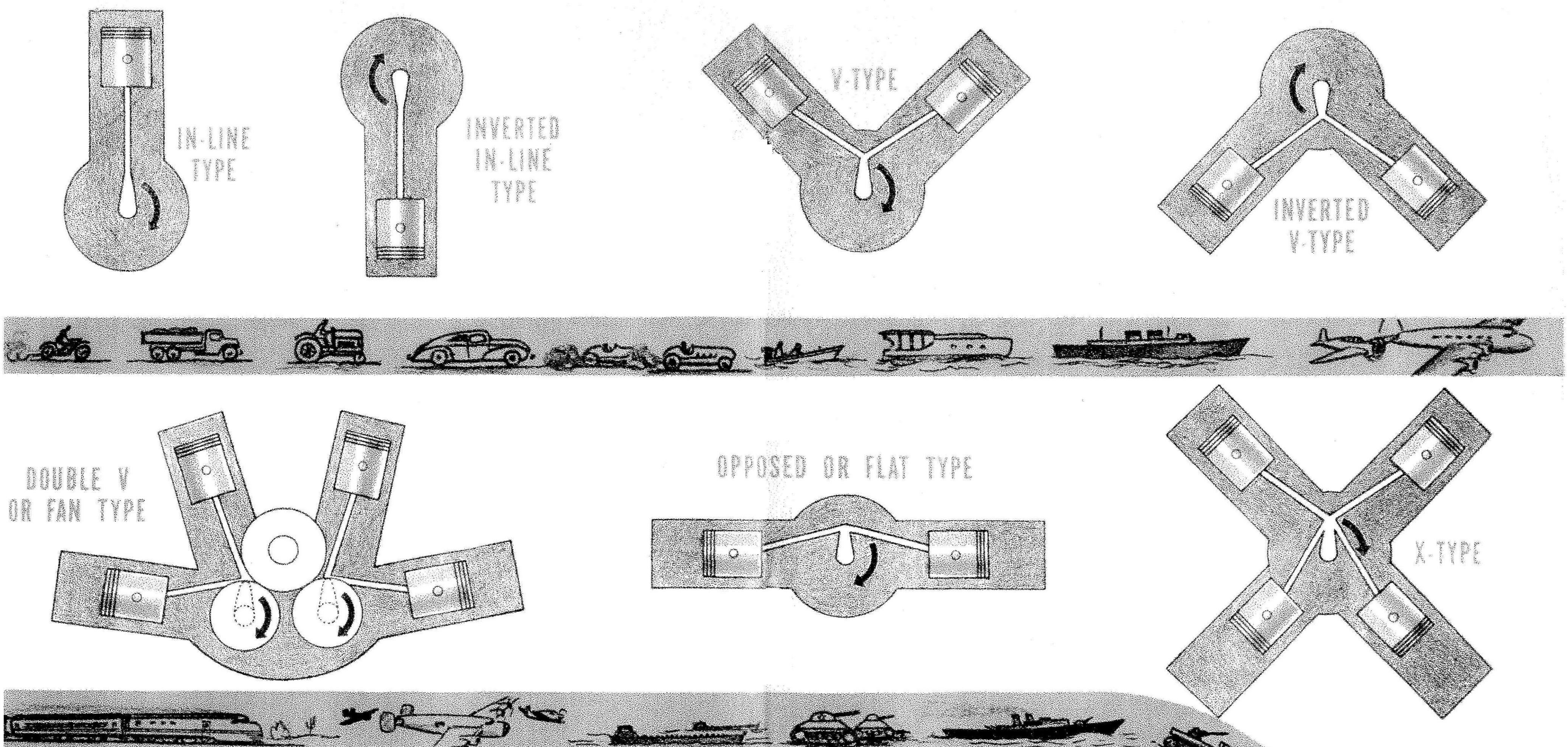
Here is one little comparison that illustrates the point. The crankshaft of one V-type automobile engine weighs 90 pounds and must be strong enough to take care of the 150 horsepower developed by the engine. One V-type aircraft engine has a similar crankshaft weighing 103 pounds—only a little more than the other—and it transmits *1325* horsepower.

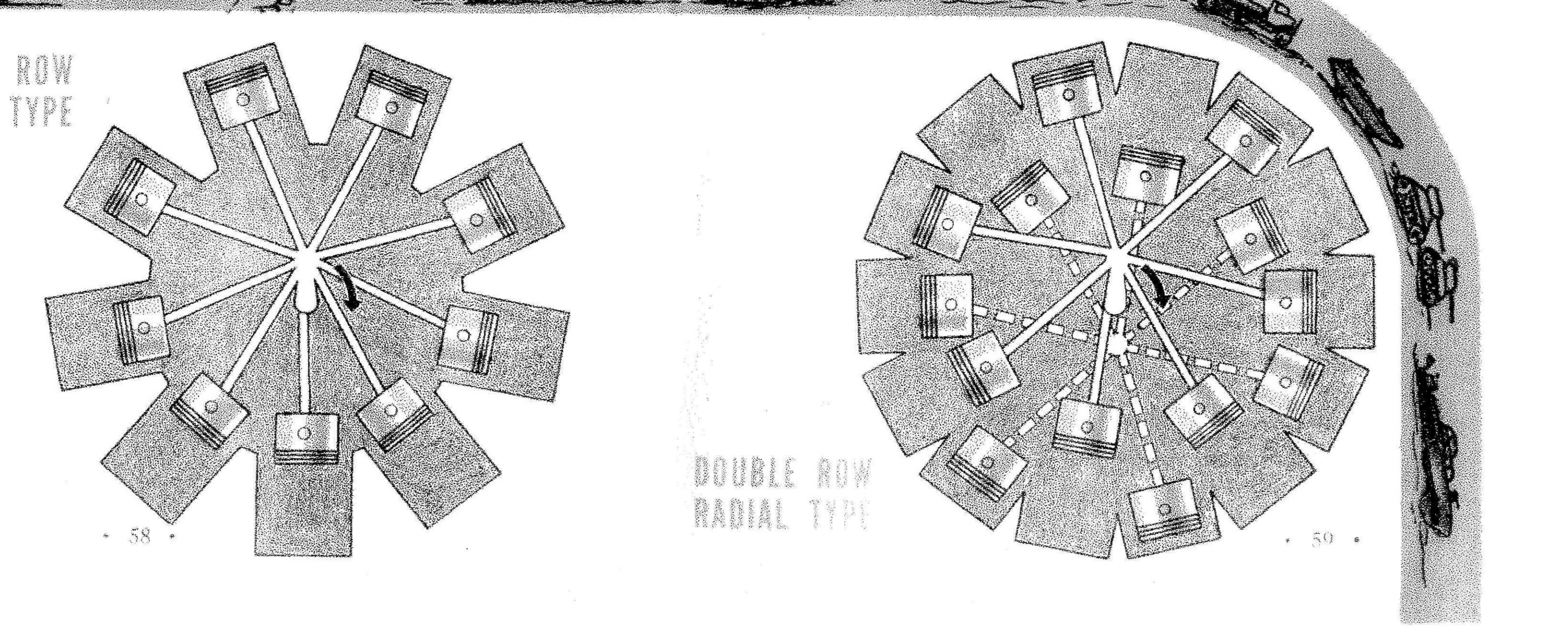


It would be possible to build automobile engines in the same way we build aircraft engines. But very few people could afford to buy those automobiles. In airplanes, weight is so important that we are willing to pay a good price for anything which will make them lighter.

Aircraft engines come in many different forms. They vary according to how they are going to be used and what kind of plane they are going to be used in. They may have the same cylinder arrangements we have already seen in automobile engines, as well as some new ones. (See pages 58–9.) There are in-line and V-type engines. There are horizontal opposed and radial engines. Some of them are turned upside down, with the crankshaft above the cylinders. And there are all sizes, from 50 horsepower up to several thousand.

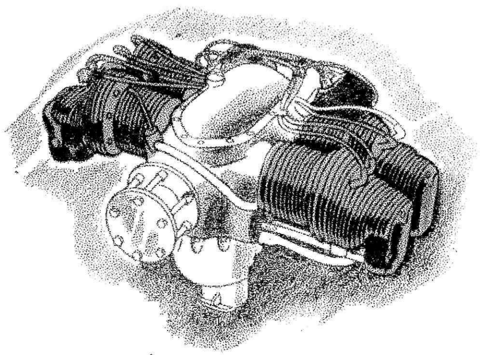
But if we get back to the fundamentals, if we dig down inside to the actual working parts, they look very familiar to us. We find the same basic unit working in the same way. We find a four-cycle gasoline engine, with cylinder and piston, connecting rod and crankshaft. It is the same situation we have mentioned before — we have simply taken a lot of single-cylinder engines and combined them in the arrangement which seems most suitable.





ENGINE TYPES

Engines are made up of a number of individual cylinders put together in various ways. Which way they are arranged depends on what the engine is to be used for. It may be determined by the space available, cooling requirements, streamlining, or other considerations.



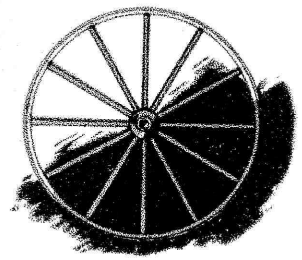
Many of the smaller engines are of the flat, **horizontal opposed** type. We might think of it as a V-type in which the V has been flattened out to 180°. They are air-cooled, but carry over many features from the automobile engine.

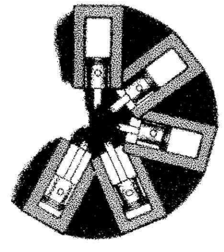
It is when we get into the larger sizes that we find more differences. There are two varieties of these larger engines—the air-cooled **radial** and the liquid-cooled **V-type.** These are the engines we will discuss in more detail. They are the ones used in the fighters and bombers, in the large transports and cargo planes. They are the furthest removed from the automobile engine, so in pointing out their distinctive features, we will automatically cover much of the ground in between. But it should be borne in mind that *all* the statements in the following pages do not apply to *all* aircraft engines.

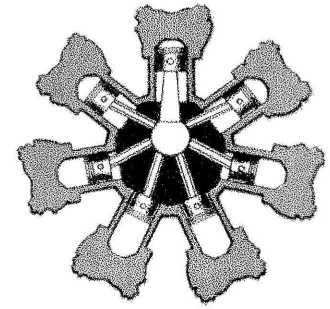
MECHANICAL FEATURES

THE most important differences between aircraft and automobile engines involve—as usual—those three things we have mentioned so often—air, fuel and ignition. But before we get into those, let us take a quick look at the mechanical arrangement and some of the other features of these large airplane engines.

We will consider the air-cooled radial engine first. To form this engine we take a number of our basic cylinder units, let us say seven, and spread them out radially around a center. A radial engine is like a large wagon-wheel, with the cylinders for spokes and the crankshaft for the axle. It is backward from the usual wagon-wheel



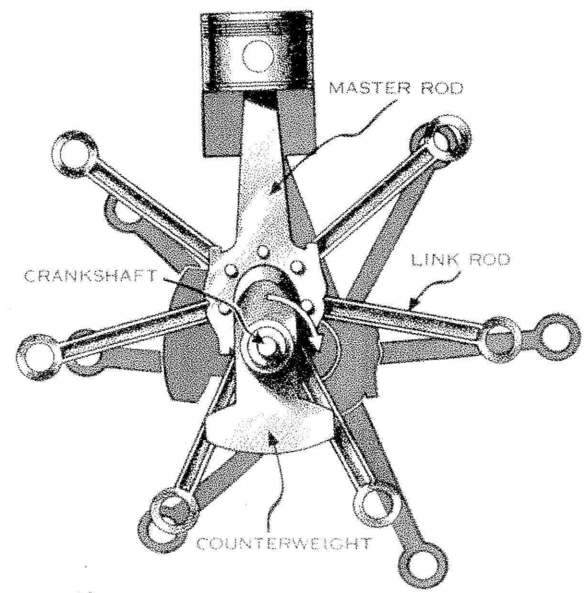


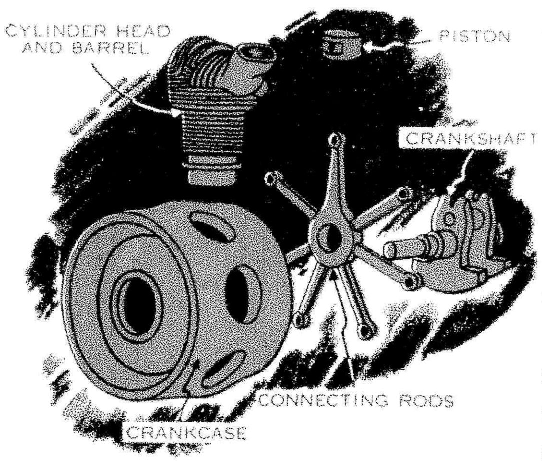


however, for the spokes stand still and the axle goes around.

There have been engines in which the axle—crankshaft—stood still and the wheel—cylinders—went around. Some early aircraft engines were built this way, the idea being that the whirling cylinders would be cooled better. These were called **rotary** engines, and should not be confused with the present **radial** engines. We sometimes hear people speak of rotary engines when they mean radial, but they are really two different things.

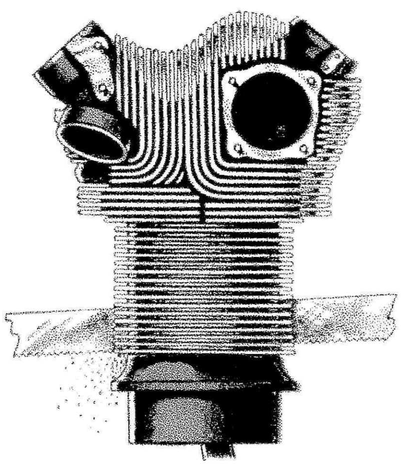
There is only one crank, or throw, to the crankshaft of a radial engine. It is just like a single-cylinder crankshaft. It has two large counterweights for balancing. The seven connecting rods must be fastened to it in some way, but there is not enough room to do it in the usual manner. So we have what is called a **master rod.** This has its small end fastened to one of the pistons and its big end around the crank pin just as if it were a single-cylinder engine. The big end is enlarged however, and has pins spaced around it to which are fastened

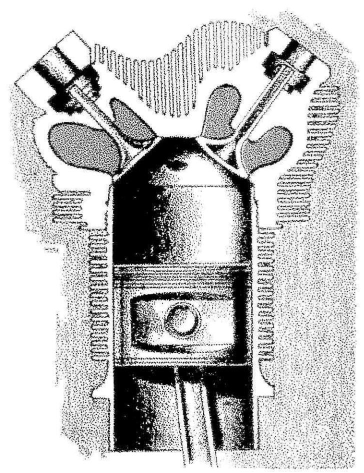




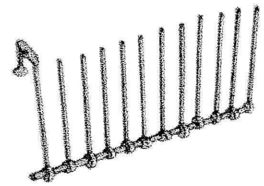
the **link,** or **articulated, connecting rods** from the other pistons. Thus the power from all the cylinders is really transmitted first to the master rod and from there to the crankshaft. But for all practical purposes it is just the same as if each connecting rod were fastened directly to the crankshaft.

In a radial engine the crankcase is somewhat like a wide hoop or ring. It has holes around it into which the individual cylinder barrels fit. On top of each cylinder barrel fits its head, which includes the valves. This is an overhead valve mechanism, with the valves set at an angle making a peaked roof on the combustion chamber. There are rocker arms and push rods just like an automobile engine. But the cams are on a ring or round plate

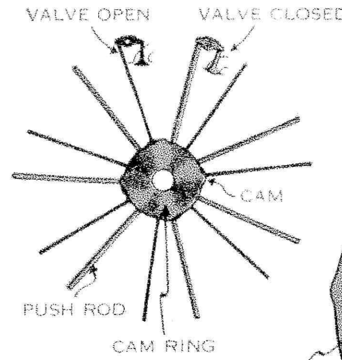


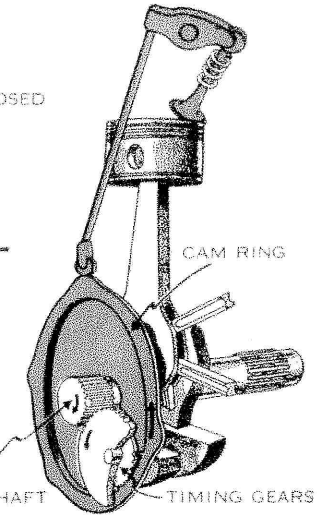


instead of on a shaft. There are two cam tracks, one for the intake valves and one for the exhaust valves. As the ring goes around, the cam opens one valve after another. There are usually several cams on each track, which



An automobile type

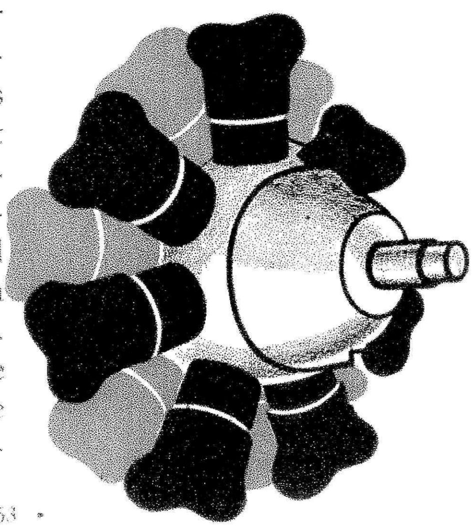




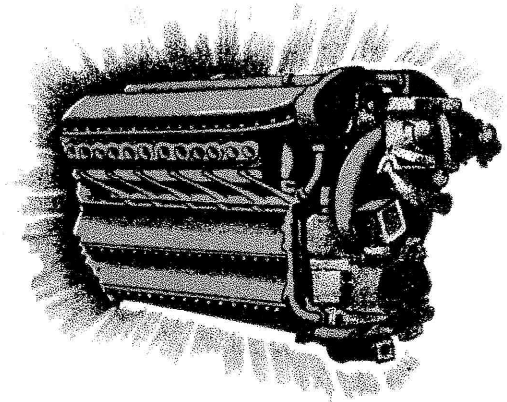
Radial aircraft type

simply means that the ring goes around that much more slowly.

We have said this is an air-cooled engine. One of the main reasons for arranging cylinders radially is to get them all out in the open where the cooling air can pass over and around them, and where they will all get equal amounts of air. With an in-line engine, it is not so easy to get an even flow of air to all the cylinders. There are fins around the cylinder and on the head to give as much cooling surface as possible for the air to reach. At some particularly hot spots, such as around the exhaust valves, more fins are provided than in other places. It is easier to cool an airplane engine by air than it is an automobile engine. It is practically always moving through the air at high speeds, it does little running with the vehicle stationary, and it gets the added benefit of the air being blown back over it by the propeller.

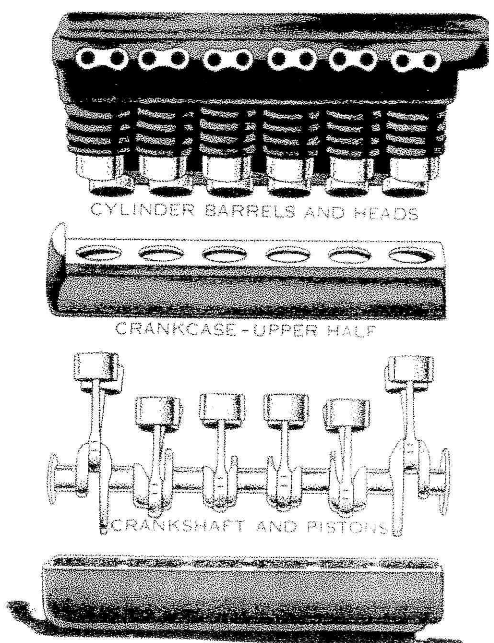


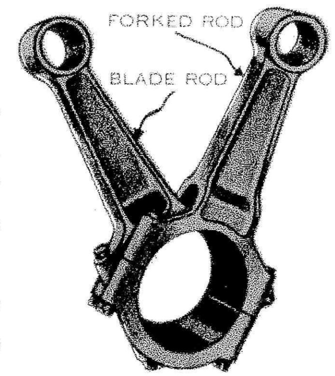
Some radial engines have two **banks.** That is, there is one row of seven or nine cyl-



inders, and right in back of this is another row of the same number. The rows are staggered. The cylinders in back are located in the spaces left between those in front, so they receive enough air for cooling. It is really almost the same as putting two complete engines together back to back. We use a crankshaft with two cranks, just as if we were adding another cylinder to a single-cylinder engine.

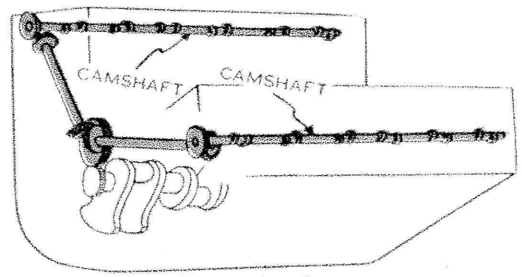
The other variety of high-power aircraft engine which we are going to discuss, the V-type, looks more like an automobile engine in general appearance and cylinder arrangement. It is longer and bigger, but its outline is very similar to the V-type engines used in cars. If we pick a typical engine, however, and take it apart so we can see the inside of it, we find some differences in the way it is made. There is an aluminum alloy crankcase, but instead of a cylinder block, there are individual steel barrels fitting into holes in the crankcase. An aluminum head, which contains the valves, fits over all the cylinder barrels in one bank. The connecting rods, instead of being all alike and fastening side by side to the crankshaft, are what is called



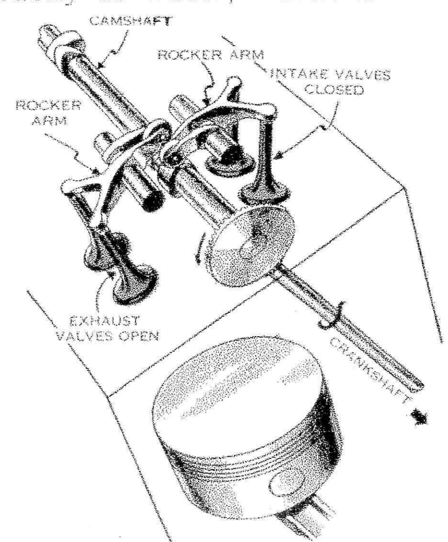


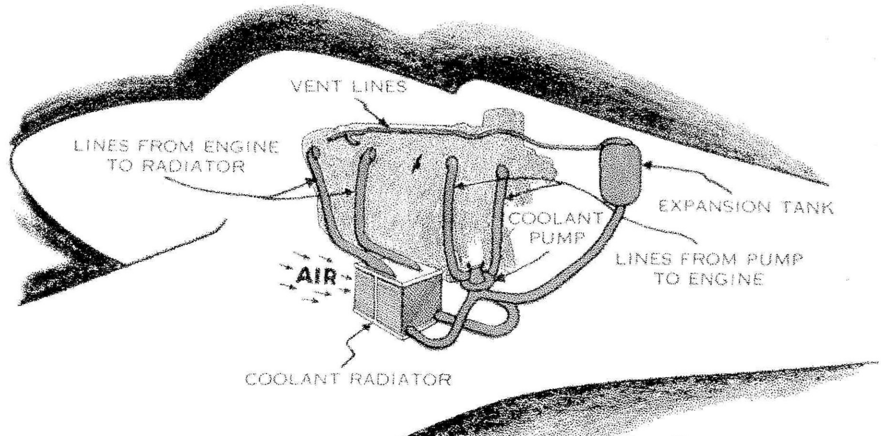
the **forked** and **blade** type. The rod from a cylinder of one bank of the V is forked at the big end, and the rod from the corresponding cylinder of the other bank slides in between the two parts of the fork.

Overhead valves are used, and the camshaft is overhead also. There are four valves in each cylinder, two intake and two exhaust. The camshaft is right above the center of the cylinders between the intake and exhaust valves, and opens them by means of short rocker arms. The rocker arms are forked so that one cam works the two intake valves and another cam the two exhaust valves.



We have mentioned that this is a liquid-cooled engine. It is not *water*-cooled. Ethylene glycol, which we put into our automobile radiators as an anti-freeze, is used as the coolant. This is not only a good anti-freeze, but it does not boil as easily as water, which is important in flying at high altitudes. In general the cooling system is the same as we have previously described. An aluminum jacket is fastened around the cylinder barrels of each bank, leaving space inside for the liquid to flow. A pump forces the liquid through the engine and then to a radiator where it is cooled. The radiator may be located anywhere on the plane as long as air can

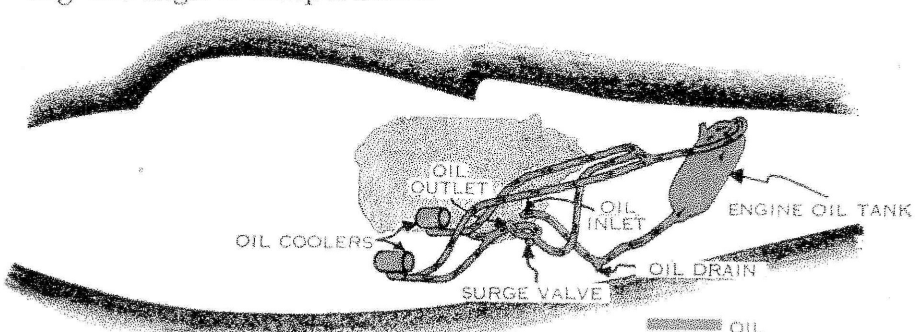




Typical aircraft cooling system

get at it and pass through it—in the nose, in the wing, or even in the fuselage.

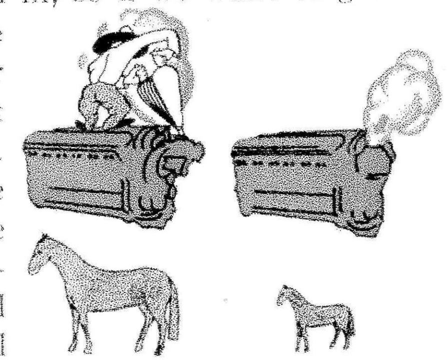
The lubrication system for this engine, as well as for the radial, differs little from those in automobiles. A pump forces oil under pressure to such points as the main bearings, connecting rod bearings, camshaft, etc. The piston pins and cylinder walls get their oil from the "splash" from the other points. The main difference is the use of the **dry-sump** system. Instead of carrying the oil supply in the crankcase, it is stored in a separate chamber outside the engine. In addition to the usual pressure pump, one or more scavenging pumps is provided to return the oil to the storage chamber from the engine. There is also usually a radiator to keep the oil from reaching too high a temperature.



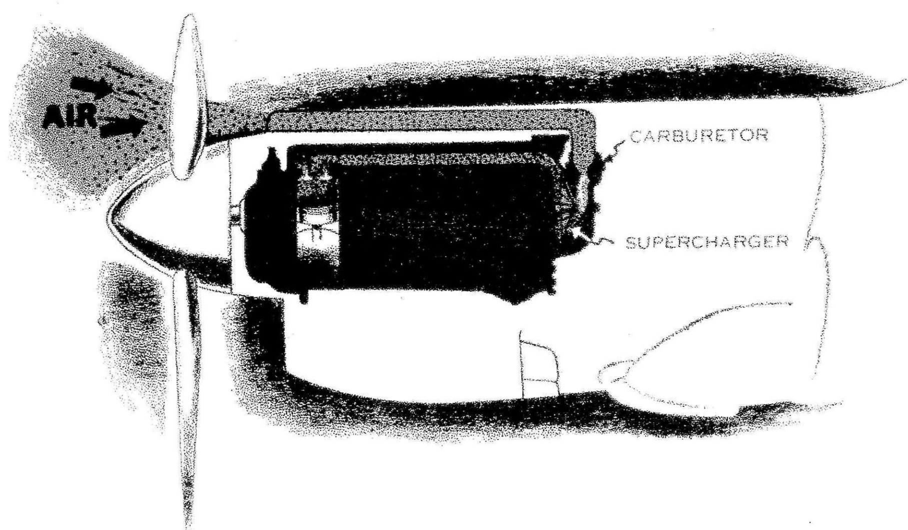
Typical aircraft lubrication system

AIR

THE more air and fuel we can get into the cylinders, the more power we will get from the engine. There is no trouble in getting plenty of fuel in, so if we want to get the most power from an engine of a certain size and weight, our main problem is to see that it gets as much air as it can handle.



With aircraft engines we are always trying to get more power without making the engine bigger. So we use special means to get more air and fuel into the engine. Instead of depending on the pressure of the atmosphere to push the mixture into the cylinder, we blow it in. We add to the engine a **supercharger,** sometimes called a **blower.**



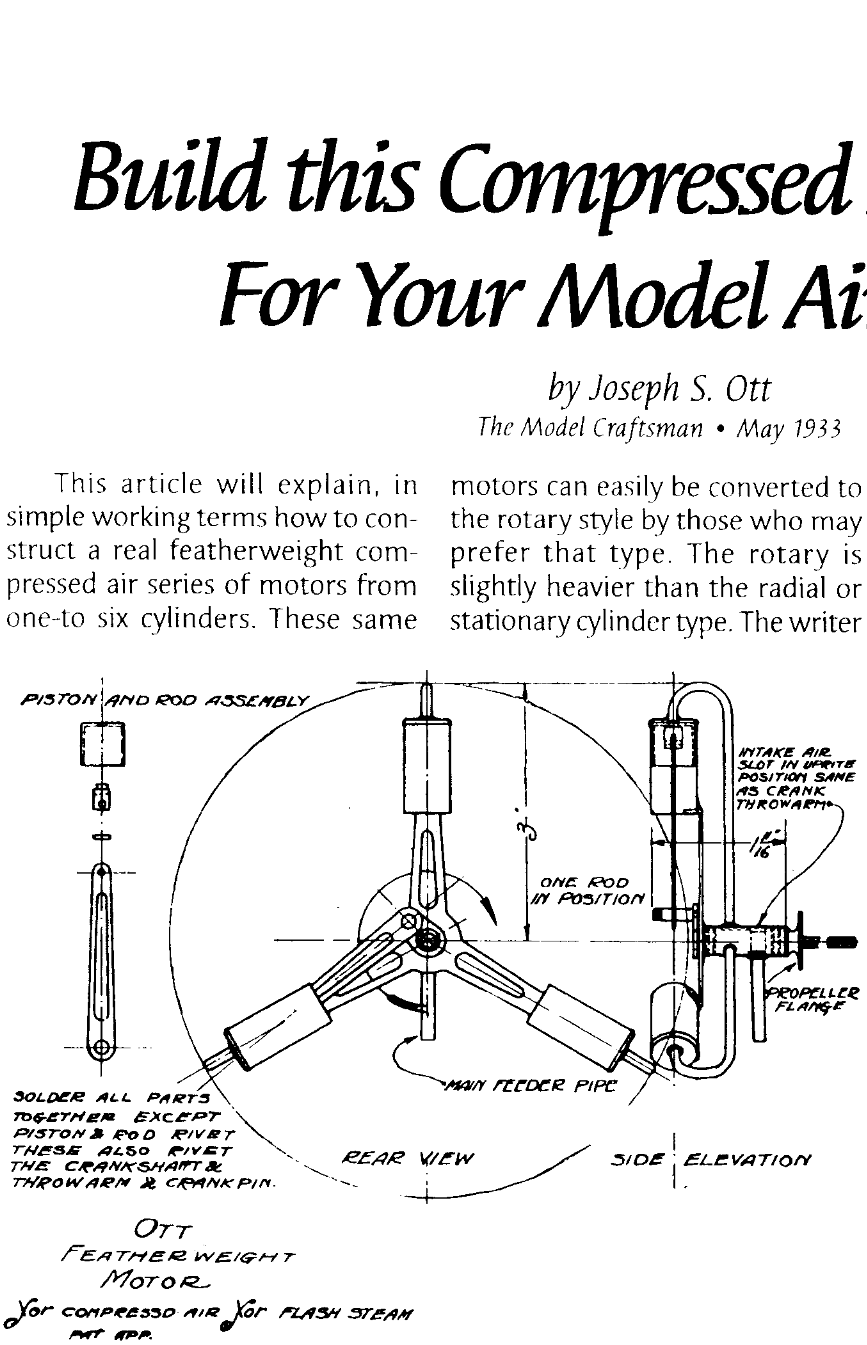
MODEL CRAFTSMAN MAGAZINE, 1933
LINDSAY PUBLICATIONS REPRINT, 2000

Build this Compressed Air Engine For Your Model Airplane

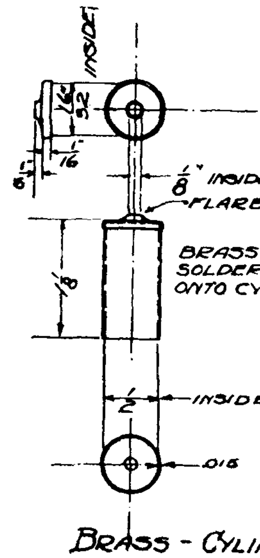
by Joseph S. Ott

The Model Craftsman • May 1933

This article will explain, in simple working terms how to construct a real featherweight compressed air series of motors from one-to six cylinders. These same motors can easily be converted to the rotary style by those who may prefer that type. The rotary is slightly heavier than the radial or stationary cylinder type. The writer does not mean, by stating that the rotary is heavier, that it is actually very much heavier. No! for example, a three-cylinder, which is the ideal type and one of the best performers, was built for comparison and its total weight was actually only 28 grams, not even an ounce. It is well to state at this time that if your motor weighs as much as 1-1/2 ounces, it still can be considered very light and in the featherweight class. The advisable procedure is to study all the sketches and pictures thoroughly and decide definitely upon the number of cylinders you wish to have on your completed motor. The writer of this article strongly indorses a three-cylinder motor. This type wil give a maximum power in relation to its length of run on a tank full of compressed air. It will fly a model having a wing spread of from five to eight feet and swing a propeller with sufficient pulling or



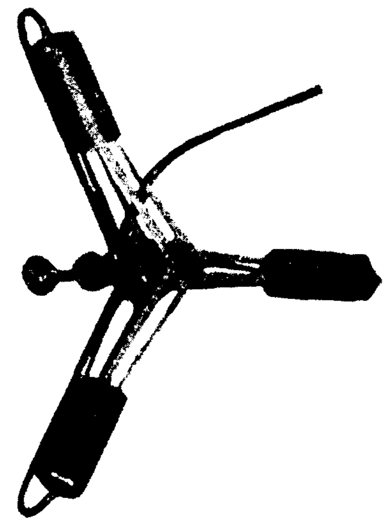
pushing power for real flight efficiency. By using a propeller measuring from 12" to 20", you may expect between 700 and 1600 revolutions per minute. The R.P.M. are dependent on the pitch of the propeller. To be exact, the length and pitch of the propeller used are the governing factors for the derived revohations per minute speed.



FRAME

The first move in the construction of the motor is to make the metal frame which holds the cylinders in position. This is best made of hard bronze, but brass may be used quite successfully. Lay out the piece of metal to be cut and a steel scratch point draw out the design for the number of cylinders desired. The frame metal is about 1/32" thick and can be cut out with a scroll saw and finished to proper size with a file.

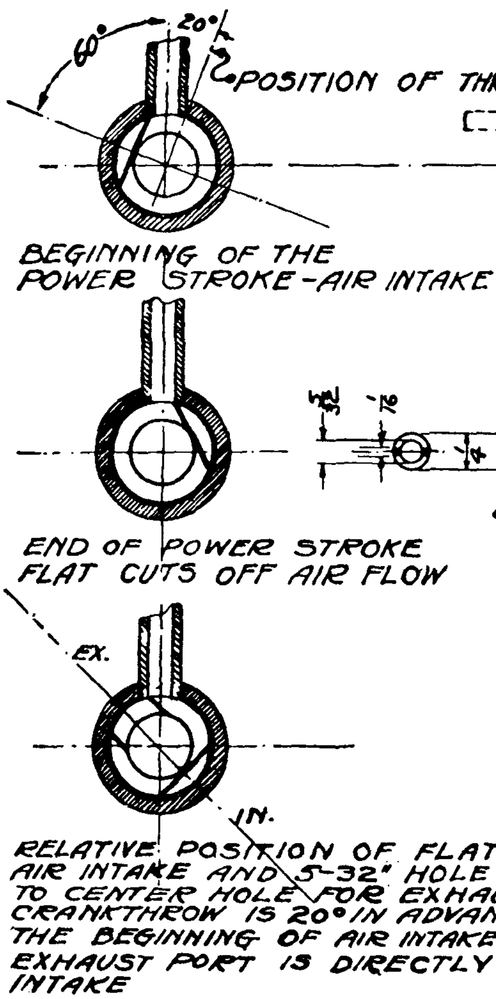
Small holes can be drilled along the design scratched on the metal for the admission of the saw blade. See the drawing of the three-cylinder frame for determining your dimensions. The "T" shaped ends of the frame are carefully formed to fit the contour of the outside cylinder wall.

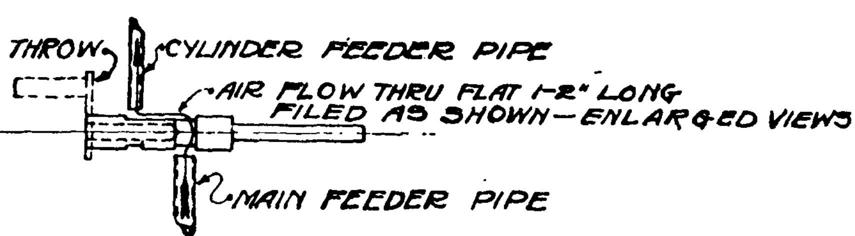


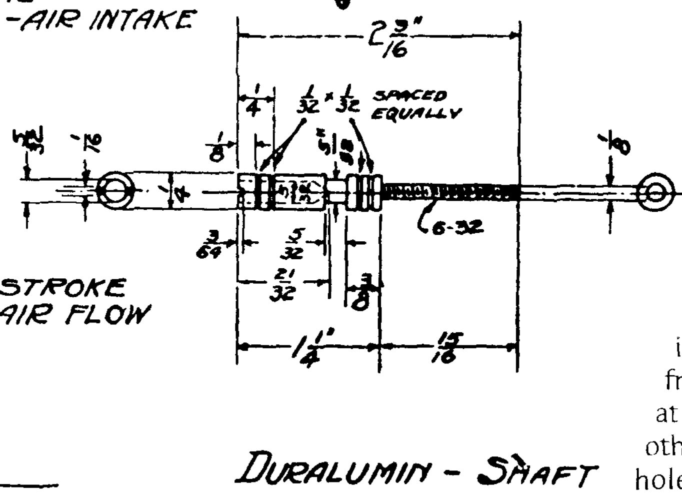
Compressed air motor constructed and tested by author

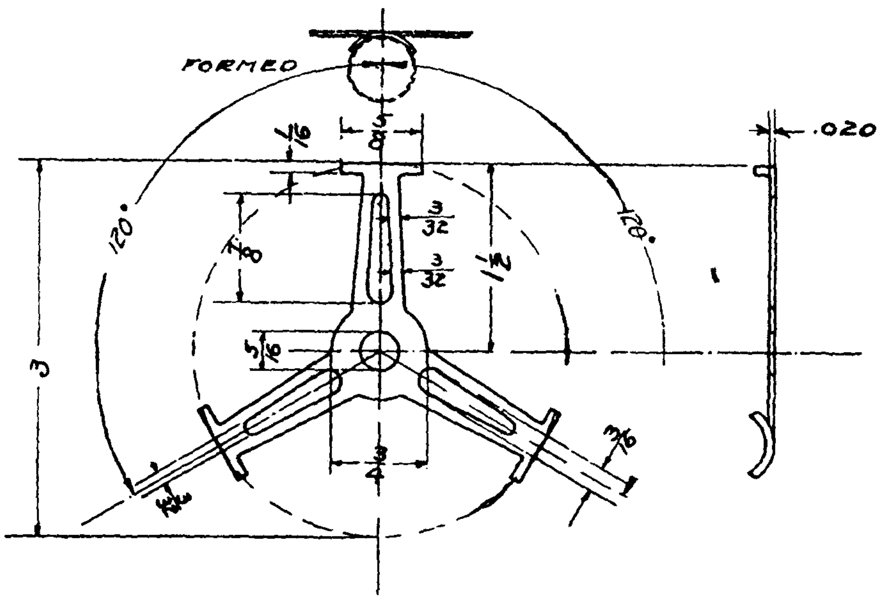
BEARING

The bearing or Brass Shaft Sleeve is next to consider. Study the drawing and cut the piece of brass tubing to the correct length. Square up the ends of the tubing with a file. The shaft sleeve bearing is next soldered into the center hole of the frame. It is very essential that the frame and bearing be exactly at right angles to one and the other. A good plan is to drill a hole large enough to fit the bearing in a block of hard wood, using a drill press so that the hole will be really vertical. Insert the bearing in the hole and slip the frame over it so that it will lay flat on the block of wood. Allow the bearing to protrude through the frame hole for about 1/32". Use a hot soldering iron, which flows the solder freely. A hasty half-

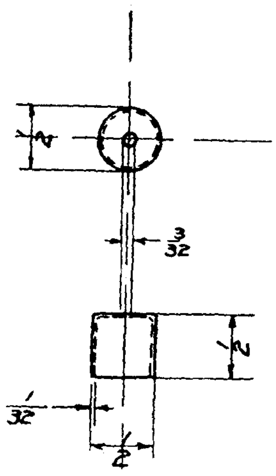






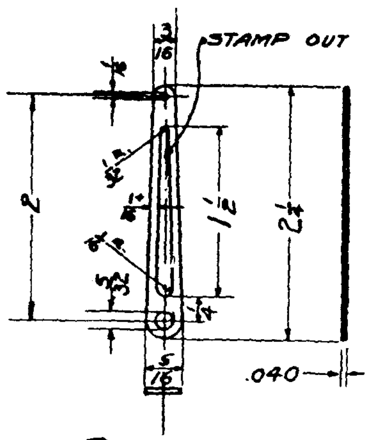


Hard Bronze-Frame



Duralumin- Piston

soldered job is to be avoided, as the motor will only break later. Use a good non-corrosive flux in conjunction with hard alloy solder and a little touch with a hot soldering iron will flow the solder so that you will have a strong everlasting job. The inlet holes and the main feeder hole should be drilled after the bearing and the frame are soldered together as then the holes can be lined up in their proper relation with the frame arms.



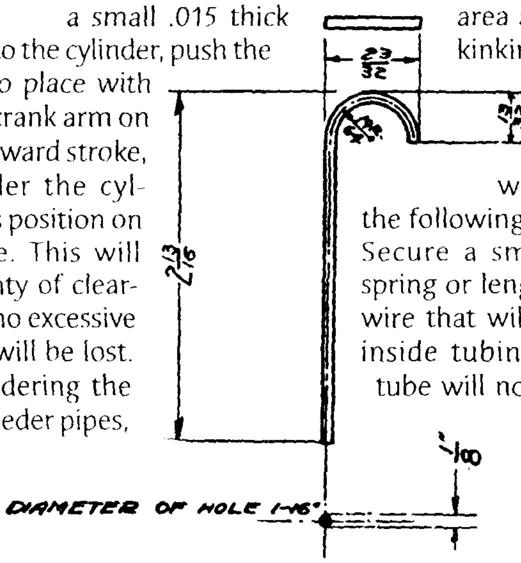
Duralumin Connecting Rod

CYLINDERS

The cylinder is cut from 1/2" inside diameter brass tubing. Care should be executed to get the cylinders the proper length. If the cylinder is too short the top of the piston will hit against the top of the cylinder. To be on the safe side, cut the cylinder 1/16" longer than shown in the drawing and in fitting, file a little off to get the exact length desired. Small .015 of an inch thick washers should be soldered to the cylinders to form the heads. Before assembling the cylinders onto the frame, make up the remaining parts, as they are necessary for fitting purposes. When you have one piston and rod assembled, insert a small .015 thick washer into the cylinder, push the piston into place with the shaft crank arm on the full upward stroke, then solder the cylinder in its position on the frame. This will allow plenty of clearance and no excessive air space will be lost. When soldering the cylinder feeder pipes, be sure the small holes are not filled up with the solder. In soldering these feeder pipes onto the bearing, *do not push the* pipe ends into the holes, just allow them to lay snugly over the hole and solder. If they are pushed through too far, the pipe ends may interfere with the rotation of the shaft inside the bearing.

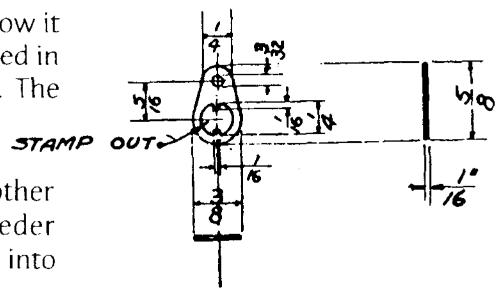
CYLINDER FEEDER PIPES

The cylinder feeder pipes are made up of 1/8" brass tubing, with an inside hole diameter of 1/16". Study the drawing before attempting to shape the feeder pipes. There is quite a trick to bending small tubing without losing the inside hole area and also avoiding kinking and folding of the pipe. After much experimenting, the writer discovered the following simple methods: Secure a small strong steel spring or length of steel piano wire that will just fit into the inside tubing diameter. The tube will not usually bend in its original cold, hardened state, so it is heated, taking out the temper. It is best to let it

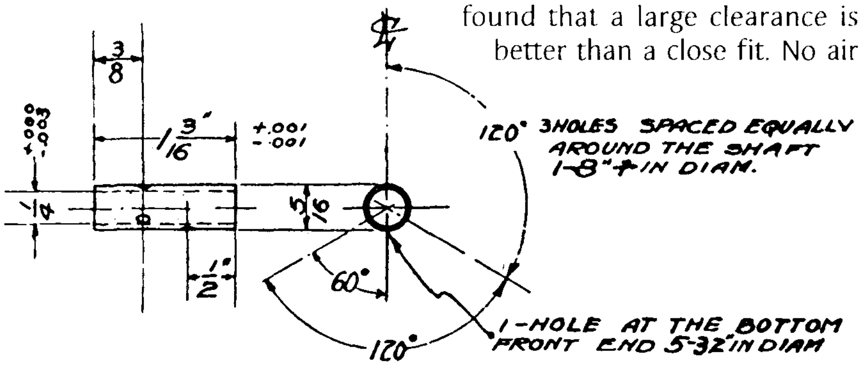


Brass Tubing
Cylinder Feeder Pipe

get a cherry red, and then allow it to cool off. It may be immersed in water to hasten the cooling. The tube may then be bent to the desired shape without losing its inside hole diameter. Another method of bending the feeder pipes is to put the cold tubes into a shallow pan and melt rosin, so that it will flow into the tubing. This is best done by cooking the hole over a gas flame. Fish out the tubes and allow them to cool off with the rosin inside them. You can then bend them to shape and heat them to remove the rosin.



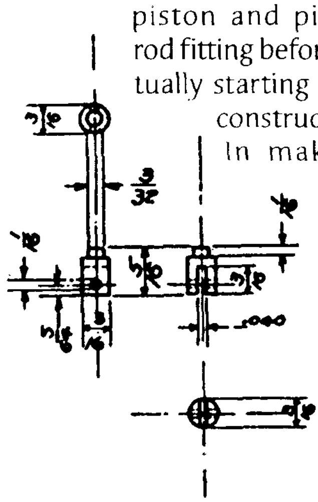
DURALUMIN OR STEEL - CRANK THROW



BRASS - SHAFT SLEEVE

PISTONS

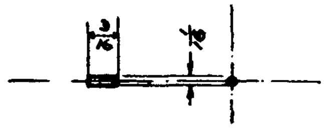
The pistons are made of duralumin and are provided with a small 3/32" diameter hole in their head for the admission of the piston rod fitting. Study the drawing of the piston and piston rod fitting before actually starting their construction. In making, the pistons, a clearance fit of, from one to two thousandths between them and the cylinder will be safe. If the pistons are made to fit closer they will tend to stick. It has been found that a large clearance is better than a close fit. No air will escape if a medium or even a heavy motor car oil is used for lubrication. Avoid the use of light household machine oils commonly found in most every home. The perfect working piston clearance is just .001" between the cylinder and the piston.



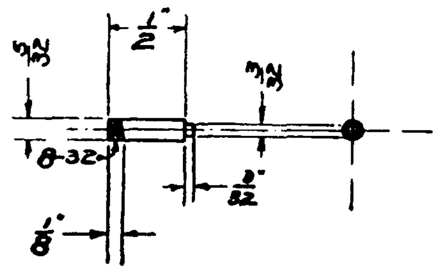
DURALUMIN-PISTON-ROD FITTING

SHAFT

The working of the whole motor depends on the proper construction of the shaft. It should be made so that it has a very close fit inside the shaft sleeve but should not rub. The clearance between the shaft and the sleeve should be .0005" and it is necessary to have the fit just right so that the shaft will turn very readily. The whole frame should spin around very easily when the shaft is in place. The timing is the most important feature and should be made a very precise job. In no case must the air begin to enter the cylinder until the crank throw is actually over the past top dead center by 15 degrees. This might seem a whole lot to those familiar with large motor construction, where the engine actually fires before the piston reaches top dead center. The writer has spent much time making different shafts and finding the best positions for the intake of air. The outcome of these extensive experiments is very carefully plotted for the builder in the drawings. Remember, that there is no firing necessary here and the compression needed in an internal combustion motor is not the case with compressed air. The air pressure is always present and constant, in fact, just "raring" to go and only will the motor go when the timing is correct. The writer is not trying to make this job look too difficult, but only impressing the reader that successful operation of the motor depends on the accuracy of the timing. If the air enters just a little too soon, the best made compressed air motor will only stand still in that position. With a little careful attention to the tim-

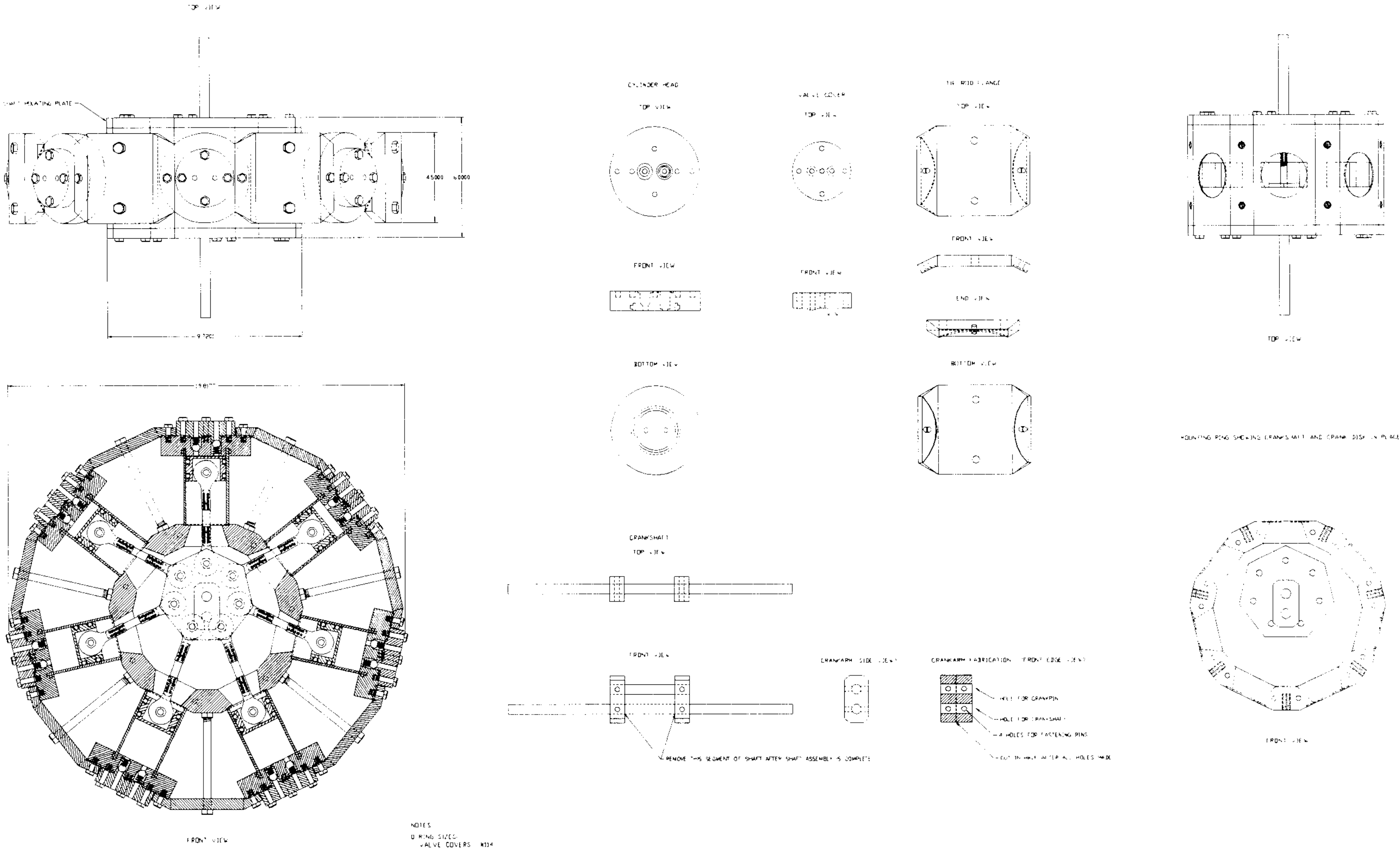


BRASS - WRIST PIN TUBING 1/32" HOLE



DURALUMIN OR STEEL - CRANK ARM

ing chart, the motor will be so timed that it will run very fast and have plenty of power. It is well to state here that the intake of air in each cylinder is dependent on the size of tubing used for feeder pipes. It is a good policy to draw up a timing chart three to five times larger than full size and then plot the relation between the fits on the shaft and the feeder pipe openings accordingly. The exhaust is simple, just opposite the intake, drill a small hole, using a 3/32" drill, and later ream the hole out with a larger sized drill, say about 5/32". If for any reason, you need more exhaust, increase the diameter of this hole up to 3/16", which is still safe.



NOTES

O RING SIZES:
  VALVE COVERS: #114
  CYLINDER HEADS: #226
  PISTON RINGS: #326
ROD ENDS:
  CRANK DISK:
    FAFNIR REP5F5
  PISTONS
    REP5FL5
NOT PICTURED
  CRANKSHAFT BEARINGS
  CRANK DISK BEARING
  MOUNTING
  CHECK VALVE BALL DIAMETER
  TOLERANCES
  BALANCED FLYWHEEL
  INTAKE FILTERS, OUTLET PLUMBING FITTINGS/PORT SPECS

MATERIALS
  CYLINDERS: FILAMENT-WOUND TEFLON IMPREGNATED EPOXY (BLACK AMALGON BA200)
  DYNAMIC O-RINGS: VITON
  STATIC O-RINGS: BUNA-N
  MOUNTING RING: ALUMINUM
  TIE ROD FLANGES, CONNECTING RODS, CRANKSHAFT, CRANK DISK, SHAFT MOUNTING PLATES: STEEL
  VALVE COVERS, CYLINDER HEADS, PISTONS, CHECK VALVE BALLS: STAINLESS STEEL
  TIE RODS, BOLTS: GRADE 8 BOLTS

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